ABSTRACT: The continuous fermentation of a working liquid wherein the circulation of the working liquid takes place through two chambers in succession, the entire mass being involved in the general flow, said chambers having unequal useful horizontal cross sections, the whole or the greater part of the gas by which the circulation is obtained being blown in the vicinity of the bottom of the ascending portion of the circuit which has the smallest cross-sectional area, said mass being subsequently transferred at a lower flow rate into the descending flow chamber having a greater cross-sectional area, whereby the ratio of the times of the ascending and descending movements of said mass considered as having a uniform mean density, ranges from 0.8 to 0.05.
CONTINUOUS FERMENTATION METHOD AND DEVICE

BACKGROUND OF THE INVENTION

In the technique of the continuous growth of micro-organisms from low-value starting materials with the minimum energy expenditure for gas blowing and stirring purposes, the fermentation devices having given the best results during the last few decades are those in which the batch is kept under regular internal circulation and so arranged that the circuit comprises two phases, i.e. a relatively fast upward or ascending phase during which most of the elements fed thereto are absorbed by these micro-organisms, and a lower downward or descending phase in which the internal metabolisms take place in anaerobiosis or in any case in a very moderate aerobicism, by using propitious media further containing all the elements necessary for the growth of the micro-organisms.

This continuity makes it possible to obtain at all points of the circuit such stable, controllable and adjustable mechanical, physical, chemical and biological conditions as can be determined or calculated beforehand. This regular circulation permits transforming the aerated wort into a homogeneous fluid consisting of an intimate mixture of gaseous and liquid substances. The relatively low density of the pseudomulsion thus obtained varies according to the kind of wort to be processed. After a few minutes a physical medium having a substantial homogeneity, as far as its weight is concerned, is obtained throughout the mass or batch, its specific gravity being slightly greater at the bottom of the vessel, due mainly to the static pressure prevailing therein. The upper layer cannot separate by density, provided that the rate of flow is kept at a sufficient value. Thus, the wort to be treated is distributed into a film having an extremely high degree of fineness and a great surface area.

By distributing the gas and the whole or part of the foods at the bottom of the ascending phase one may, knowing the momentary batch outputs flowing at this point, calculate the various feeds in order to apportion the same to the weight of micro-organisms passing at any time. Thus, the feed values are so adjusted that during the ascending phase the substances will be consumed up to the predetermined and desired values, as a function of the medium available and of the constant micro-organisms content.

Thus, the micro-organism will always perform its metabolism in a medium remaining substantially constant at each point thereof, this medium undergoing but slight and continuous variations. The micro-organism is well adapted thereto and can thus grow in a medium the carbon content of which, in an assimilable form, is as low as desired. The proportion of the carbon fed thereto along the circuit, preferably upstream of the insulation zone, is as low as desired and consumed very rapidly.

In the case of aerobic fermentation devices requiring the use of a strong aeration, the latter produces the internal circulation.

It is often endeavoured to increase the rate of this circulation by blowing more air than required for oxygenating the micro-organisms and in case the resulting energy expenditure would be abnormally high a mechanical acceleration may still contribute to any desired extent to this circulation rate.

However, the extrapolation of these fermentation devices cannot be extended indefinitely as far as their proportions are concerned. Their magnification is attended by constructional problems, notably in consideration of cost, and also by problems of hydrodynamics which would obviously call for costly solutions.

SUMMARY OF THE INVENTION

Now, I have discovered that, proportionally, very satisfactory results can be obtained by using large-capacity fermentation devices and causing the two ascending and descending phases of the aforesaid circuit to take place in two different enclosures of smaller dimensions, in lieu of a single enclosure attaining prohibitive dimensions. To this end, the present invention provides a continuous process for fermenting and producing any micro-organism, wherein the working liquid mass circulates in a regular, permanent closed circuit, the mass being maintained constant by properly setting the feed and extraction rates. The aforesaid circulation is obtained by blowing gas at a rate sufficient to cause on the one hand the complete batch to be transformed, after a certain revolution time, into a low-density fluid consisting of gaseous and liquid substances, and on the other hand to keep the speed impressed to said batch at a value high enough for converting this batch, when normal operative conditions and rates are attained, into a substantially homogenous mass or, in other words, to cause the gas-to-liquid ratio by weight at any point of the vessel to remain substantially constant and to vary along the circuit according to a constant law taking due consideration for the insulation rate and the higher gas extraction rate.

The circulation takes place in a complex enclosure consisting essentially of two chambers disposed externally of each other but interconnected at their upper and lower portions. The circulation takes place through said chambers in succession, the entire batch being involved in the general flow. The said chambers have unequal horizontal cross sections, and the whole or the greater part of the gas is blown in the vicinity of the bottom of the ascending portion of the circuit which has the smallest cross-sectional area, so that a high turbulence and a high rate of flow are imparted to said fluid mass during its upward movement. The mass is subsequently transferred at a lower flow rate into the descending flow chamber having a greater cross-sectional area, whereby the ratio of the times of the ascending and descending movements of said mass considered as having a uniform mean density, ranges from 0.8 to 0.05. The fluid circulation from the smaller chamber to the larger chamber creates for the entire mass of said fluid a substantially horizontal upper surface common to the upper portion of the two chambers and of the means interconnecting them.

It is another object of this invention to provide a device for the continuous fermentation of all micro-organisms, which consists of two adjacent vessels having substantially vertical side walls and different cross-sectional areas, said vessels communicating with each other by their upper and lower portions and comprising means for blowing gas into the lower portion of the smaller vessel in order to produce a continuous circulation of the working mass. The ratio of the cross-sectional areas of said two vessels ranges between 0.8 and 0.05. The means provided for blowing gas into said smaller vessel is capable of impressing to the ascending phase a relatively great speed of the order of 0.5 to 2 meters per second and to produce in addition a great turbulence. The communication circuit means between the two vessels are designed with a view to reduce frictions losses, the overflow threshold of the ascending stream into the descending stream lying beneath the upper mean level common to both vessels containing the moving gas-liquid fluid constituting a continuous mass without any discontinuity.

BRIEF DESCRIPTION OF THE DRAWING

The attached drawing illustrates typical forms of embodiment of this invention. In the drawing:

FIG. 1 is a diagram for explaining the principle on which this invention is based;
FIG. 2 is a part-sectional side-elevational view showing a first form of embodiment of the invention;
FIG. 3 is a plan view thereof;
FIG. 4 is a view similar to FIG. 2 but showing another form of embodiment;
FIG. 5 is another plan view of a further modified form of embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The basic diagram of FIG. 1 illustrates the mode of circulation of the fluid through a single circuit comparable to that contained in an irregular tore having a vertical plane of sym-
metry and of which the upper portion c is only partially filled. The vertical portions a and b, and the lower portion d have different cross-sectional areas calculated to cause the rates of flow at each point of the circuit to correspond to those found by practical experience with one-vessel fermentation devices. Thus, the principal aeration and feed take place at the base of the narrowest portion a, by means of pipe lines 1 and 2. The gas is expelled in the substantially horizontal upper portion c connecting, in a substantially horizontal circulation, the ascending phase to the descending phase. The lower portion d connects the descending phase to the ascending phase and in the example illustrated the fluid is extracted at 3 from the lower portion of the descending phase.

Under practical conditions this diagram lends itself to different solutions yielding the above-mentioned results if it is endeavored to meet the best possible constructional requirements and to obtain the best possible performances as far as frictional losses are concerned.

Of course, these solutions permit of extracting the fermented mass at the most favorable point along the descending phase, of inserting at will in the circuit a cooling or heating device 4, and of selecting for the sake of better convenience a mechanical accelerator 5 whenever such means may prove useful for the scope contemplated.

By way of example, the continuous or closed circuit illustrated in FIGS. 2 and 3 may thus be constructed, which comprises a vessel a in which the ascending and descending phases are separated, a vessel b parallel to said vessel a, which may be a simple tank disposed adjacent vessel a and may even be joined or tied thereto, with or without a slight interpenetration. These vessels a and b are notched at 6 and 7 at such a level that the working mass flows from vessel a into vessel b above the base 8 of the upper portion c, below a level 9 common to the vessel a and b, and need only be emulsified, without making it compulsory to raise the mean mass in vessel a at a level substantially higher than that obtaining in vessel b.

The relatively short connection c between vessel a and vessel b enables the entire mass emerging from vessel a to flow into vessel b due to the motion thus created, with the minimum loss of pressure, and the other connection d interconnects the lower portions of these two vessels.

With this arrangement the rate of flow of the mass emerging from vessel b, after a change in its direction, is accelerated, if due account is taken of the paths capable of minimizing losses of pressure; it permits mounting either at its inlet at 5, or along said path, or at the outlet thereof, a helical accelerator having the maximum diameter. It also permits mounting a heat exchanger 4 deriving a beneficial effect from the already accelerated flow rates. It also provides the feed points 2 required for the fermentation process as well as the insufflation zones 1.

The main additions necessary for the fermentation process which are incorporated in said vessel a are properly distributed throughout the mass by any suitable and known means.

The vessels a, b and c may be provided with suitably shaped covers for closing the complete fermentation device, these covers being also capable, if desired, to withstand a certain pressure. In this case, the gas is exhausted from the upper portion of the assembly.

The flow at c may take place preferably tangentially into the vessel b as shown in FIG. 3, so that a rotary motion can be maintained in said vessel b.

This vessel b may also be provided in its axial position with a concentric cylinder 10 closed at both ends and suitably streamlined, for the purpose of preventing a privileged flow of the descending mass; this cylinder may also be open at both ends as illustrated in FIG. 4 and receive a secondary insufflation at 11 for restoring a constant ascending flow centrally of the vessel; from the point of view of energy consumption this insufflation is of secondary importance and is not introduced compulsorily into the base of said cylinder. The cross-sectional area of said air cylinder will have to range from about 1/10th to about 1/40th of the total cross-sectional area of the vessel.

It was also found that, when very large production rates are contemplated, which require the use of several fermentation devices of this character, and when the same rules are adhered to, it is possible to use a single vessel b associated with a plurality of vessels a, as shown in FIG. 5.

Finally, the general arrangement of the device also permits of bringing certain changes in the general principles set forth hereinabove in respect of the homogeneity. It is assumed that the rate of flow actually controls the mean density of the emulsified fluid as well as its homogeneity which it is desired to make constant by weight. By reducing the rate of circulation or flow below a predetermined value one may obtain, as contrasted with what had been contemplated beforehand, a stable operation in which, within certain limits, there is a certain heterogeneity. In this case, as a rule, the mean specific gravity of the fluid at the top vessel b is lower than at the bottom thereof. Therefore, a kind of decantation takes place.

Under these conditions, the method of this invention, by virtue of its properly controlled continuity, will be so effective that it is the density variation, not the density itself, that is regular and constant in the vessel, within the limits preset for the selected rate of circulation.

This possibility may still be more useful if the liquid medium itself consists of a mixture of nonmiscible liquids tending to decant more or less rapidly. This feature may be advantageous; in most cases, the ether lighter medium existing at the top of the vessel will have a higher micro-organisms content, this element being effective for selecting the level wherein the micro-organisms are extracted, and the fluid existing at the lower level will have more convenient hydraulic characteristics.

What I claim is:

1. A method of continuously fermenting a working liquid and producing micro-organisms which comprises circulating said working liquid in a regular, permanent closed circuit comprising two chambers disposed externally of each other and interconnected at their upper and lower portions, said circulation taking place through said chambers in succession and the entire mass of said working liquid being involved in the general flow, said chambers having unequal effective horizontal cross sections, a chamber of smaller cross section constituting an ascending portion of said circuit, and a chamber of larger cross section constituting a descending portion of said circuit, maintaining the mass of said liquid in said circuit substantially constant by controlling the rates of feed of fluid to said circuit and extraction thereof said circulation being obtained by blowers.

2. A method of fermenting and producing micro-organisms as set forth in claim 1, wherein feed fluids are introduced in the vicinity of the bottom of said ascending flow chamber, up.
stream of the gas, so that said feed fluids are consumed mainly in said ascending phase.

3. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein the feed rate of all the components necessary for the metabolism of the micro-organisms is so adjusted that the components of said feed are absorbed sufficiently prior to the ingress of said mass into the descending flow circulation phase, and that, consequently, only minor variations take place whether in the conditions of said mass or in the nutritive compositions of said mass.

4. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein the feed is distributed at different points of the circuit, thus permitting developing different modes of fermentation along the circuit and minimizing the variations in the conditions of said mass and in the nutritive compositions thereof.

5. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein, to counteract the heat generated by the growth of the micro-organisms, the interior of the circuit is cooled in the chamber of reduced cross-sectional area in which the ascending circulation takes place.

6. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein, to promote the growth of the micro-organisms, the interior of the circuit is heated in the chamber of reduced cross-sectional area in which the ascending circulation takes place.

7. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein, in case of anaerobic fermentation, one fraction of the gas generated by the fermentation process is collected at the top of the circuit and recompressed for subsequent recycling therein.

8. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein, by virtue of a predetermined reduction in the rate of circulation of said mass, the homogeneity properties thereof are not maintained uniform in that there is an incipient decantation of the liquid with respect to the gas along the circuit path, the variation in the degree of heterogeneity thus created being nevertheless maintained by properly controlling the circulation rate within limits not to be overstepped but permitting an enrichment of the upper layers with micro-organisms in conjunction with a slight removal of gas from the lower zones of the circuit, whereby the hydrodynamic conditions are improved.

9. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein fermented fluid is extracted from said circuit in the vicinity of the bottom of said larger chamber.

10. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein said larger chamber is cylindrical and said fluid is introduced tangentially into the upper portion of said larger chamber.

11. Method of fermenting and producing micro-organisms as set forth in claim 1, wherein the circulating effect of said gas is supplemented by mechanical impulsion of said fluid mass at a portion of said circuit of reduced cross-sectional area.

12. A device for the continuous fermentation and production of any micro-organisms, consisting of two vessels having substantially vertical walls and different useful cross-sectional area, means for interconnecting said vessels at the top and bottom thereof, and other means for blowing gas into the lower portion of the smaller vessel in order to produce the continuous circulation of the working mass, wherein the ratio of the cross-sectional areas of the two vessels ranges from 0.8 to 0.05, said gas blowing means being sufficient for imparting to the ascending phase a relatively high speed of the order of 0.5 to 2 meters/second and producing in addition a great turbulence, the circuits interconnecting the two vessels being arranged with a view to reduce frictional losses, the threshold of overflow of the ascending flow into the descending flow lying above the upper mean level common to both vessels of the gas/liquid circulating mass constituting a continuous mass without any discontinuity.

13. Micro-organisms fermentation and production device as set forth in claim 12, wherein the outlet for the ascending flow towards the descending flow vessel is deflected with respect to the plane comprising the axes of the two vessels in order to produce an asymmetric overflow adapted to maintain the rotation of the mass of fluid during its descending phase, so as to avoid preferential paths in said descending phase.

14. Micro-organisms fermentation and production device as set forth in claim 12, wherein a mechanical accelerator is provided in a restricted portion of the fluid circuit in order to accelerate the rate of flow of the fluid in circulation.

15. Micro-organisms fermentation and production device as set forth in claim 12, wherein a heat exchange means is installed within the circuit, in said ascending flow smaller vessel.

16. Micro-organisms fermentation and production device as set forth in claim 12, wherein a closed volume is provided in said descending flow vessel, coaxially thereeto.

17. Micro-organisms fermentation and production device as set forth in claim 12, wherein a cylindrical enclosure communicating with the descending flow vessel unit is arranged centrally thereof and coaxially thereeto, together with means permitting the insufflation of gas from the bottom upwards through said enclosure.

18. Micro-organisms fermentation and production device as set forth in claim 12, wherein a descending flow vessel is common and interconnected with a plurality of ascending flow vessels.

19. Micro-organisms fermentation and production device as set forth in claim 12, wherein said vessels are closed and adapted to operate under pressure.

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